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PHYSICAL EXAMINATION IS THE BEST PREDICTOR OF THE NEED FOR ABDOMINAL SURGERY IN CHILDREN FOLLOWING MOTOR VEHICLE COLLISION

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Abstract

Background—Exploratory laparotomy in children after motor vehicle collision (MVC) is rare. In the absence of definitive hemorrhage or free abdominal air on radiographic imaging, predictors for operative exploration are conflicting.

Objective—The purpose of this study was to explore objective findings that may aid in determining which children require operative abdominal exploration after MVC.

Methods—Data from 2010–2014 at an American College of Surgeons–certified level 1 pediatric trauma center were retrospectively reviewed. Demographics, vital signs, laboratory data, radiologic studies, operative records, associated injuries, and outcomes were analyzed and $p < 0.05$ was considered statistically significant.

Results—Eight hundred sixty-two patients 0–18 years of age presented to the hospital after an MVC during the study period. Seventeen patients (2.0%) required abdominal exploration and all were found to have intraabdominal injuries. Respiratory rate was the only vital sign that was significantly altered ($p = 0.04$) in those who required abdominal surgery compared with those who did not. Physical examination findings, such as the seat belt sign, abdominal bruising, abdominal wound, and abdominal tenderness, were present significantly more frequently in those requiring abdominal surgery ($p < 0.0001$). Each finding had a negative predictive value for the need for operative exploration of at least 0.98. There were no significant differences in trauma laboratory values or radiographic findings between the 2 groups.

Conclusion—Data from this study solidify the relationship between specific physical examination findings and the need for abdominal exploration after MVC in children. In addition, these data suggest that a lack of the seat belt sign, abdominal bruising, abdominal wounds, or

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abdominal tenderness are individually predictive of patients who will not require surgical intervention.

Keywords

children; injury; motor vehicle crash; seat belt sign

INTRODUCTION

Unintentional injury is the leading cause of death in children >1 year of age, and motor vehicle collision (MVC) is the leading cause of death in children 8–18 years of age (1,2). Seat belt use is a crucial method to decrease the risk of severe injury and death in children involved in MVC (3,4). However, shortly after the introduction of seat belts in 1960, the "seat belt syndrome" was described—a combination of abdominal wall bruising (AWB), intra-abdominal injury (IAI), and lumbar spine fracture—raising concern that seat belts may cause a unique set of injuries (5). Subsequently, multiple reports found that a positive seat belt sign (SBS) was associated with an increased risk for IAI (6–11). In addition, children remain at increased risk for seat belt–related injury caused by improper restraint use (12,13). The probable mechanism of seat belt injury is direct loading over the injured organ (14).

The optimal evaluation algorithm to identify blunt IAI in the pediatric population includes a combination of history and physical examination findings, laboratory values, and imaging modalities (15–21). The majority of pediatric blunt IAIs are managed conservatively; however, the need for abdominal exploratory surgery persists in select circumstances.

Literature describing predictive factors for the need for abdominal exploratory surgery in pediatric patients presenting with blunt trauma after MVC is scarce. A study of 1400 patients over a 3-year period at a major trauma center concluded that SBS was associated with a higher incidence of IAI (9). Likewise, Paris et al. concluded that associated lumbar fracture, free intra-abdominal fluid, and tachycardia were highly predictive of intestinal injury in children with AWB and the need for laparotomy after MVC (8). However, this study was limited to patients presenting with AWB and may have missed patients with IAI in the absence of this physical examination finding. Other studies have presented conflicting data, and have suggested that the SBS is not associated with an increased risk of abdominal injury or need for abdominal surgery (22,23).

The objective of the present study was to determine predictive factors associated with the need for abdominal exploratory surgery in children sustaining blunt abdominal injury after MVC. We hypothesized that a combination of laboratory, physical examination, and radiographic findings would be predictive of the need for operative intervention in children with blunt abdominal trauma.

METHODS

Patient Selection

A single-center retrospective query of the pediatric trauma database was performed for all blunt trauma–related encounters incurred over a 5-year period between January 1, 2010 and

December 31, 2014. Institutional review board approval was obtained before the search. Patient medical records were assessed for demographic variables and initial vital signs, physical examination findings, laboratory values, and trauma-related imaging results. These were compiled into a master database. Patients were subsequently divided into those who underwent abdominal surgery for their injuries and those who did not undergo abdominal surgery.

Assessed Variables

Continuous variables were considered in 2 groups: initial vital signs (i.e., heart rate, systolic and diastolic blood pressure, temperature, unassisted respiratory rate, and Glasgow coma scale) and initial trauma laboratory panel (i.e., hemoglobin, hematocrit, white blood cell count, aspartate transaminase, alanine transaminase, amylase, and lipase). Vital signs and laboratory values were additionally considered as binomial variables, categorized into normal and abnormal variables. Other categorical variables included physical examination findings (i.e., presence or absence of the SBS, abdominal bruising (AB), abdominal tenderness, or open abdominal wound) and radiographic findings on computed tomography (free pelvic fluid or pneumoperitoneum).

Statistics

Continuous variables were expressed as mean ± the standard error of the mean and were compared using Student's *t*-test. Categorical variables were compared using chi-squared tests. $p < 0.05$ was considered statistically significant.

RESULTS

Patient Population

Eight hundred sixty-two patients ranging from 0–18 years of age were assessed in the hospital after MVC during the study period. Eight hundred fifty-seven patients had complete medical records, including documentation of physical examination findings and laboratory values of interest; these patients form the basis of this report. Seventeen patients (2.0%) required abdominal exploration while 840 did not require an abdominal procedure.

Operative Findings

Seventeen patients (2%) underwent operative intervention. Of these patients, 15 (88%) were identified appropriately on their first admission and operated on immediately after trauma. Two of 17 patients (12%) exhibited none of the physical examination findings of interest. One patient was discharged and readmitted 4 days later with a delayed presentation of a jejunal perforation. The other patient presented in a delayed fashion with small bowel obstruction 12 days after trauma. Each patient who underwent surgical intervention was found to have an IAI (Table 1). There were no negative laparotomies.

Vital Signs

Initial recorded heart rate, blood pressure, temperature, and Glasgow coma scale were not significantly different between those children requiring operative intervention for their abdominal injuries and those not undergoing surgery (Table 2). The mean unassisted respiratory rate was significantly lower in those who did require operative intervention compared with those who did not (19 ± 5.2 vs. 23.5 ± 8, $p = 0.04$). There was no significant difference in the proportion of patients in each group who had abnormal vital signs (Table 2).

Laboratory Panel

There were no significant differences in the laboratory values between the 2 groups either by comparison of the means or by comparison of the proportions of patients with abnormal values in each group. Laboratory values assessed included white blood cell count, hemoglobin, hematocrit, aspartate transaminase, alanine transaminase, alkaline phosphatase, amylase, and lipase (Table 3).

Physical Examination Findings

Table 4 shows the predictive qualities of the following physical examination findings: SBS, AB, open abdominal wounds, and abdominal tenderness. There was a significant difference between the operative group and the nonoperative group in the presence of each of these findings.

One hundred sixty-one patients (18.7%) had a positive SBS. Twelve of 17 patients (70.6%) who underwent surgery had a positive SBS, while 149 of 840 (17.7%) patients who did not require surgery had a positive SBS ($p < 0.001$). The relative risk (RR) of needing surgery with a positive SBS was 9.09 (95% confidence interval [CI] 3.5–24.0). The negative predictive value (NPV) was 99.3 (95% CI 98.5–99.7).

Eighty-four patients (9.8%) had AB. Seven (41.2%) of 17 patients who underwent laparotomy had AB, while only 77 patients (9.2%) of 840 who did not require operation had AB ($p < 0.001$). The RR of surgery with AB was 6.0 (95% CI 2.4–15.0). The NPV was 98.7 (95% CI 98.1–99.1).

Twenty-one patients (2.5%) had open abdominal wounds. Thirteen (76.4%) of 17 patients who underwent laparotomy had an open abdominal wound, while 8 (1.0%) of 840 who did not require surgery had an abdominal wound ($p < 0.001$). The RR of surgery with open abdominal wound was 20.7 (95% CI 8.0–53.8). The NPV was 99.5 (95% CI 98.9–99.1).

One hundred nineteen patients (13.9%) had abdominal tenderness (AT) or signs of peritonitis. Thirteen (76.4%) of 17 patients who underwent laparotomy had AT or peritoneal signs. One hundred and six patients (12.6%) who did not have surgery had AT ($p < 0.001$). The RR of surgery with AT was 21.8 (95% CI 7.3–65.2). The NPV for surgery with AT was 99.5 (95% CI 98.7–99.8).

Radiographic Findings

Overall, 324 patients (37.8%) underwent computed tomography (CT) imaging of the abdomen and pelvis. Fifty-one patients (15.7%) had evidence of free pelvic fluid (FPF). Sixteen patients who underwent laparotomy had a CT scan, with 5 (29.4%) having evidence of FPF. In the nonoperative group, 307 patients (36.5%) underwent CT scan, and 47 (15.3%)

of those maintained FPF on CT scan. The presence of FPF did not reach statistical significance as a predictor for laparotomy.

DISCUSSION

Predictive models to determine which children need abdominal surgery after blunt abdominal trauma are conflicting. Herein, we determined that physical examination findings are the most reliable in predicting which children will require an abdominal procedure after MVC. With the exception of respiratory rate, initial vital signs appear to be equivalent among surgical and nonsurgical patients. Laboratory values also do not appear to predict which children will require surgery. The presence of specific physical examination findings, such as the SBS, AWB, abdominal wound, or AT are associated with a higher likelihood of abdominal intervention. Most importantly, patients who lack these signs are appropriate for nonoperative, conservative management.

This study is one of the larger series on this topic with >800 patients studied over 5 years. As expected, this study shows that few pediatric patients actually require an abdominal operation after being involved in a MVC. Of course, patients who are hypotensive or obviously hemorrhaging require laparotomy, but decision making in the hemodynamically stable patient remains much more challenging.

With this in mind, obtaining vital signs remains the first assessment of a traumatic patient. Tachycardia is usually one of the first vital signs to be observed in patients who are in shock, with hypotension resulting from severely injured patients who may be hemorrhaging or who have not been adequately resuscitated (24). Indeed, other studies have suggested that tachycardia was an independent predictor of intestinal injury, and therefore of the need to undergo an operative intervention (8). However, we observed no difference in mean heart rate or proportion of patients with abnormal heart rate between the 2 groups. This is a good reminder that patients with a normal heart rate may still require abdominal operation. Children have a greater capacity than adults to compensate, and therefore may present as hemodynamically stable despite ongoing blood loss or perforated viscous. It is unclear why the only vital sign parameter to be different between the operative group and the nonoperative group in our study was respiratory rate. We hypothesize that depressed respiratory rate might have been associated with increased pain and splinting because of abdominal injury, but a definitive correlation cannot be determined. Despite this difference in mean respiratory rate, there was no difference between the 2 groups in proportion of patients with abnormal respiratory rate.

We were also surprised to note that there were no significant differences in laboratory values between the operative and nonoperative groups. There were differences in the means of various laboratory parameters, with the operative group having higher levels of aspartate transaminase, alanine transaminase, and lipase, which makes sense given that those who required operation had IAIs. However, none of these were statistically significant, and there was no difference between the groups when comparing the proportion of patients with abnormal laboratory values. Interestingly, the initial hemoglobin and hematocrit levels were not different between groups, likely because hemoglobin does not typically drop early in the course of trauma, but later once resuscitation and equilibration have occurred. In addition, the main source of anemia in blunt trauma patients is solid organ injury, and this is rarely an indication for laparotomy in children.

The most significant predictive factor for surgical abdominal injury in blunt trauma in children appears to be physical examination findings. Findings including the SBS, AWB, abdominal wound, and AT or peritonitis were each independently significantly more associated with the operative than the nonoperative group. Despite this association, the positive predictive value for these factors was quite small, possibly because of the small sample size in the operative group. On the other hand, the lack of each of these physical examination findings had a strong NPV for the need for operative intervention. This would suggest that those children lacking any of the four physical examination findings would not require abdominal intervention.

Limitations

This study has several limitations. First, it was a retrospective study. As such, the data acquired are only as reliable as what was recorded during the initial patient encounter. Only 5 patients from the database had any missing data, and they were excluded, which only accounted for 0.6% of the total population studied.

An additional limitation is that only 2% of the population studied required an abdominal procedure, which makes the intervention group quite small. The small size of the intervention group therefore allowed for larger variability in measured parameters within the operative group. Although this does lead to the potential for the study to be underpowered, this remains the largest series of these patients, and our rate of operative intervention is similar to national averages.

CONCLUSIONS

Physical examination findings are the best predictive measures for determining whether a child requires laparotomy after blunt abdominal trauma. In this study, a positive SBS, AT, open abdominal wound, or AB was noted more commonly in children who required abdominal operation after traumatic injury, and the lack of these findings strongly predicted that the child did not need surgery. These examination findings may assist clinicians in determining which children may require an abdominal operation in the absence of overt findings, such as hemorrhage or shock.

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ARTICLE SUMMARY

1. Why is this topic important?

A small percentage of pediatric blunt trauma patients require operative exploration for their abdominal injuries. In the clinically stable patient, this decision is difficult and no definitive guidelines exist.

2. What does this study attempt to show?

This study attempts to evaluate objective differences between patients who require surgery and those who do not after blunt abdominal trauma. Examination findings, laboratory values, and radiographic findings were assessed to come up with criteria to aid in decision-making.

3. What are the key findings?

Patients who required operative intervention were no different in terms of initial vital signs, laboratory results, and radiographic findings compared with the nonoperative group. Physical examination findings—specifically, the seat belt sign, abdominal wounds, abdominal bruising, and abdominal tenderness—were found significantly more frequently in the operative group ($p < 0.0001$). In addition, these physical examination signs had negative predictive values of >0.98, indicating that patients who lack these signs do not need an operation.

4. How is patient care impacted?

This study indicates that in a relatively stable patient, one should not rely on vital signs, laboratory values, or computed tomography as the deciding factor for surgical intervention. In addition, the negative predictive value is extremely helpful for decision making because patients without these physical examination signs likely do not require surgical exploration.

Table 1

Operative Cases

Age, Years	Gender	Posttrauma Day	Abdominal Injuries Identified at Operation	Procedure Performed
2	Female	0	Mesenteric defect with devascularized small bowel and perforation	Exploratory laparotomy, small bowel resection with primary anastomosis
2	Female	0	Pancreatic transection, splenic laceration, renal laceration, and retroperitoneal hematoma	Exploratory laparotomy with distal pancreatectomy
5	Male	0	Serosal injury to ascending colon	Exploratory laparotomy, colorrhaphy
5	Male	0	Hematoma at root of mesentery, blood and chylous fluid in abdomen	Exploratory laparotomy, evacuation of hemoperitoneum
5	Female	0	Small focus of pneumoperitoneum, jejunal mesenteric hematoma	Exploratory laparoscopy, evacuation of hemoperitoneum
7	Male	1	Traumatic ventral and flank hernia, laceration of external and internal oblique, and right common iliac dissection	Open flank hernia repair, laparotomy
9	Female	0	Traumatic abdominal wall hernia, seromuscular tears of sigmoid and right colon, and laceration of small bowel mesentery	Exploratory laparotomy, repair of small bowel mesentery, repair of colon serosal tears, and repair of traumatic abdominal wall hernia
9	Female	0	Blood in pelvis, deserosalization injury to ascending colon through hepatic flexure, and retroperitoneal hematoma	Exploratory laparotomy, evacuation of hemoperitoneum
10	Male	2	Necrotic sigmoid colon, mesenteric defect, and mesenteric hematoma	Diagnostic laparoscopy, laparotomy, and partial colectomy with primary anastomosis
10	Female	4	Delayed presentation of jejunal perforation	Laparotomy, primary repair of jejunal perforation
11	Male	0	Traumatic abdominal wall hernia, ischemic bowel with mesenteric avulsion	Exploratory laparotomy, small bowel resection with primary anastomosis, and temporary closure
12	Male	0	Grade 5 splenic injury with complete avulsion	Exploratory laparotomy, splenectomy, and temporary closure
12	Male	0	Jejunal perforation	Exploratory laparotomy with jejunal resection and primary anastomosis
12	Female	2	Spleen laceration, pneumoperitoneum without evidence of bowel injury	Diagnostic laparoscopy, evacuation of hematoma, and full exploration
13	Male	12	Mesenteric hematoma, mesenteric defect, deserosalization of jejunum, and delayed small bowel obstruction	Exploratory laparotomy, small bowel resection with primary anastomosis
13	Male	0	Perforation of proximal jejunum	Diagnostic laparoscopy, exploratory laparotomy, and primary repair of perforated jejunal injury
13	Male	0	Mesenteric hematoma with ileal devascularization	Ileal resection with anastomosis
13	Male	0	Jejunal perforation	Exploratory laparotomy, enterorrhaphy of jejunum

Table 2

Vital Signs of Trauma Patients

Initial Vital Sign	Operative Group, Mean (SEM)	Nonoperative Group, Mean (SEM)	*p* Value (*t*-Test)	Abnormal in Operative Group, %	Abnormal in Nonoperative Group, %	*p* Value (Chi-Squared)
Temperature (°C)	36.6 (0.17)	36.7 (0.06)	0.96	7.69	6.50	0.86
Heart rate	117.7 (4.94)	115.8 (0.97)	0.79	53.33	37.14	0.20
Respiratory rate	19.0 (5.2)	23.5 (8.0)	0.04	42.86	38.53	0.74
Systolic blood pressure	119.3 (4.16)	118.9 (0.58)	0.93	0.00	1.29	0.66
Diastolic blood pressure	69.3 (4.04)	69.9 (0.48)	0.85	13.33	11.87	0.86
Glasgow coma score	14.2 (0.8)	14.3 (0.09)	0.89	6.67	12.62	0.49

SEM = standard error of the mean.

Table 3

Initial Laboratory Values of Trauma Patients

Initial Laboratory Parameter	Operative Group, Mean (SEM)	Nonoperative Group, Mean (SEM)	*p* Value (*t*-Test)	Abnormal in Operative Group, %	Abnormal in Nonoperative Group, %	*p* Value (Chi-Squared)
Hematocrit	34.4 (1.19)	35.7 (0.19)	0.22	35.29	34.17	0.92
White blood cell count	16.0 (1.71)	13.9 (0.27)	0.18	68.75	64.26	0.71
Aspartate aminotransferase	160.1 (55.66)	99.9 (7.02)	0.15	35.71	35.42	0.98
Alanine aminotransferase	92.5 (31.60)	59.5 (4.70)	0.24	42.86	33.26	0.45
Alkaline phosphatase	196.3 (14.19)	201.4 (3.76)	0.82	0.00	3.77	0.46
Amylase	63.2 (13.87)	63.91 (2.92)	0.97	63.64	77.84	0.27
Lipase	54.3 (16.42)	30.6 (2.64)	0.13	38.46	18.89	0.08

SEM = standard error of the mean.

Table 4

Physical Examination Findings

Finding	Present in Operative Group (%)	Present in Nonoperative Group (%)	*p* Value	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Positive Likelihood Ratio (95% CI)	Negative Likelihood Ratio (95% CI)
Seat belt sign	12 (70.6)	147 (17.6)	<0.0001	70.6 (44.0–89.7)	82.4 (79.7–85.0)	7.6 (5.5–10.3)	99.3 (98.5–99.7)	4.0 (2.9–5.7)	0.4 (0.2–0.8)
Abdominal bruising	7 (41.2)	77 (9.2)	<0.0001	41.2 (18.4–67.1)	90.8 (88.7–92.7)	8.2 (4.7–14.3)	98.7 (98.1–99.1)	4.5 (2.5–8.2)	0.7 (0.4–0.9)
Open abdominal wound	13 (76.5)	8 (1.0)	<0.0001	76.5 (50.1–93.2)	99.1 (98.1–99.6)	61.9 (43.7–77.3)	99.5 (98.9–99.8)	80.3 (38.4–168.0)	0.2 (0.1–0.6)
Abdominal tenderness, peritonitis	13 (76.5)	106 (12.6)	<0.0001	76.5 (50.1–93.2)	87.4 (84.9–89.6)	10.9 (8.2–14.4)	99.5 (98.7–99.8)	6.06 (4.41–8.33)	0.27 (0.11–0.63)

CI = confidence interval; NPV = negative predictive value; PPV = negative predictive value.